E/CONF.39/A/124
17 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.3.4.2

Italy

SUBMERGED COMBUSTION IN SALINE WATERS DEMINERALIZATION

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SUBMERGED COMBUSTION IN SALINE WATERS DEMINERALIZATION

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1. Introduction

In the submerged combustion process a fuel (gaseous or liquid) is burned in a chamber immerged in a liquid to be treated (solution to be concentrated, liquid to be evaporated etc.) so that the products of combustion which develop in the form of numerous bubbles, will gurgle in the same liquid thus assuring efficient thermal exchange, strong agitation of the liquid and consequently higher thermal efficiency.

Submerged combustion is particularly suitable for the concentration of solutions which attack the metallic materials generally used for construction of evaporators [1, 2]; in fact, corrosion and fouling problems are noticeably decreased both due to the absence of thermal exchange surfaces and to the lower temperature existing in the combustion chamber.

Figure I shows the combustion temperature versus the ratio of effluent and effluent water solutions, at the pressure of 1 Kg/sq. cm. for three types of fuel; in all cases a feeding temperature of 60°C. was assumed, and the excess air was 0 for methane, 9 % for butane, 50 % for Diesel oil. In examining the above diagram it can be seen that, at atmospheric pressure, the maximum temperature which can be reached is about 89°C and it is reached when methane is used. The temperature can be brought to higher values by increasing the working pressure (fig. I) or by using oxygen enriche air.

In submerged combustion the heat which develops is found as sensible heat in the gas and in the liquid, and as latent heat due to vaporization of the components transferred from the liquid to the gaseous phase; the composition of the gaseous phase will obviously depend upon the nature of the liquid and of the fuel and the bulk temperature.

In cases of aqueous solutions of electrolytes, the effluent combustion gases will be in equilibrium with the water and will contain it in a quantity proportional to its vapor pressure; therefore, the ratio water vapor/dry gases will increase with the heat value of the fuel and will decrease with the rate of feeding solution.

The aim of this preliminarly study is to examine the possibility and convenience of applying submerged combustion to obtain soft water by demineralizing sea or brackish waters.

2. Application of submerged combustion to saline waters demineralization.- Flow-diagram.

Since the maximum quantity of water which can be condensated from gaseous products is about 16 Kg/kg of fuel, regardless of its type (the expense encountered for the fuel only would be of about 4.5 $/1000 ga.), the process of submerged combustion for the production of softened waters from sea-water may not result convenient cost-wise, even if we consider the simplicity of installations, absence of corrosion, etc.

But if we consider that the gaseous products (steam+combustion gas), which develop in the combustion chamber contain almost all of the heat produced during combustion, these could be used as a source of heat for a battery of multiple-effect evaporators according to a flow diagram such as the one shown in fig. II.

The wet gas is sent from the boiler to a first evaporator (head of a battery of multiple-effect evaporators) in which it will transfer part of its sensible and latent heat. When coming out, after a separator, the gas is conveyed into a second evaporator of a new battery and then to a third one. The saline water, in the mean time, is pre-heated and sent in parallel flow to the evaporators and it will then be used to feed the boiler. With this procedure, while the salt concentration is kept low in the evaporators, a noticeable concentration of same is obtained in the boiler discharge water [a].

3. Selection of fuel

The specific theoretical production and the incidence of fuel on the final cost of demineralized water have been estimated considering the fuels mentioned above, in order to select the most suitable.

Theoretical production has been calculated establishing the proper temperature drops in the head evaporators so as to have the maximum obtaibale total steam production. The steam produced in these evaporators has been multiplied by the number of effects which can be contemplated in each series, bearing in mind that the last effect works at 45°C temperature.

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[a] The diagram has been elaborated according tothe plant suggested by Standiford and Bjork [3] , adopting the same temperature differences among the evaporators of a battery and all possible heat recoveries. The number of evaporators in fig. II is merely indicative.

The results are summarized in figure III, where theoretical production is shown versus the heat value of the fuel. In the same diagram the incidence of fuel cost appears, referred to the specific theoretical production, having assumed two values as the cost of fuel i.e. 0.4 $/10^6$ B.t.u. (as recommended by the U.S. Department of Interior) [4], and 0.3 $/10^6$ B.t.u. (as adopted by Standiford and Bjork [3] for the economic evaluation of the Badger plant). The convenience of adotting fuel having higher heat value is demostrated by the analysis of these results.

4. Effect of Combustion Pressure

For methane, which is a more convenient fuel from the point of view of maximum specific production of demineralized water, the possibility of adopting boiler pressures higher than atmospheric pressure has been considered. Combustion temperature would thereby be increased implying an increase in the number of evaporators and consequently in the steam production.

The results of the economic study carried out according to the standard procedure [4] , for a 1 Mgpd plant are summarized in figures IV and V, which indicate that as combustion pressure increases:

(a) the higher the cost of fuel, the more rapidly the fuel incidence decreases;
(b) the incidence of electric energy has a very rapid increase at the beginning and a slower one later one; the higher expense for the compression of a unit volume of methane (together with the relative air) is partially balanced by a decrease in the gas rate;
(c) the cost of the plant increases very slowly; the higher number of evaporators, exchangers etc. is balanced by the smaller dimensions of the single equipment;
(d) total cost of the water increases in the case of 0.3 $/10^6$ B.t.u. fuel cost, while it decreases in the case of the 0.4 $/10^6$ B.t.u. cost, (see point a)

Considering the results obtained, it is clear that an increase of combustion pressure, which unavoidably calls for more complicated installation and working conditions, can be giustified only in particular and limited cases (low cost of electric energy, etc)

5. Effect of air enrichment

After having carefully considered the atmospheric pressure process and the methane process, the possible application of oxigen enriched air was then examined. The cost of demineralized water are reported in figure VI versus the air oxygen content, assuming that said enrichment does not bring about further expense. A notesable cost reduction may occur only in those cases where the addition of oxygen is high.

5. Conclusions

From the analysis carried out it results that the submerged combustion, coupled with multiple-effect evaporators for the assumed capacity of the 1 Mgpd plant, reaches a cost slightly higher than that estimated for the method of mere multiple-effect evaporation with saturated steam heating.

However, if we consider that costs of fuel and electric energy may vary in different Countries and that characteristics of submerged combustion are:

(a) Less corrosion and fouling;
(b) High concentration ratio in salts, suitable to obtain brines for NaCl recovery;
(c) Less expensive installations required;

it can be concluded that the process could be conveniently applied when low price fuels are available and when medium and low production of soft water is required, that is to say in cases where the installation of multiple-effect evaporators would not results economically convenient.

References

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[2] AUSTIN, J., Submerged Combustion Evaporators, Brit. Chem. Eng., 2, 490-494 (1957)

[3] STANDIFORD, F.C.jr, BJORK, H.F., Evaporation of Sea Water in Long Tube vertical Evaporators, Advances in Chemistry Series, 27, 115-127 (1960)

[4] U.S.Department of the Interior, A Standardized Procedure for Estimating Costs of Saline Water Conversion - PB 161375 (1956)

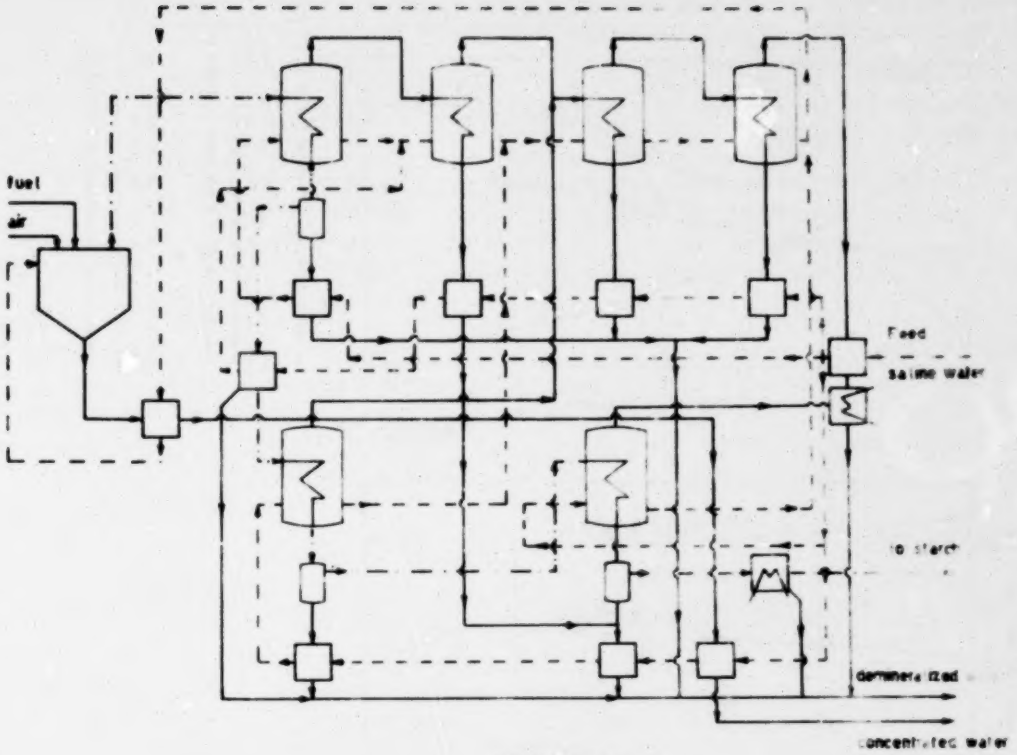

FIGURE II

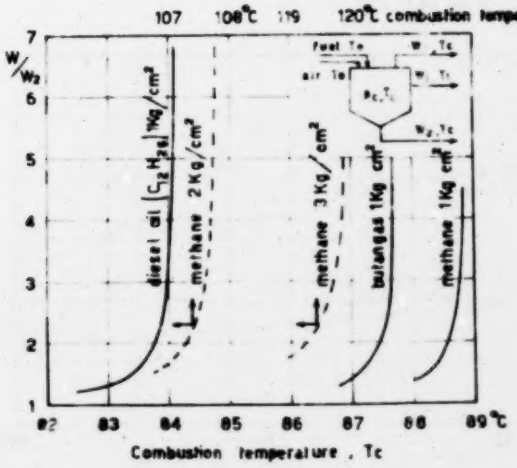

FIGURE I

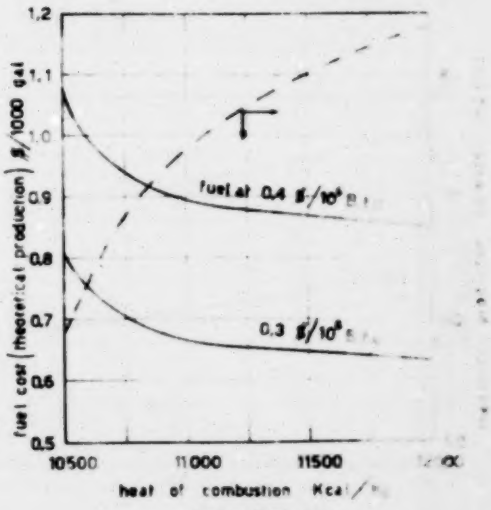

FIGURE III

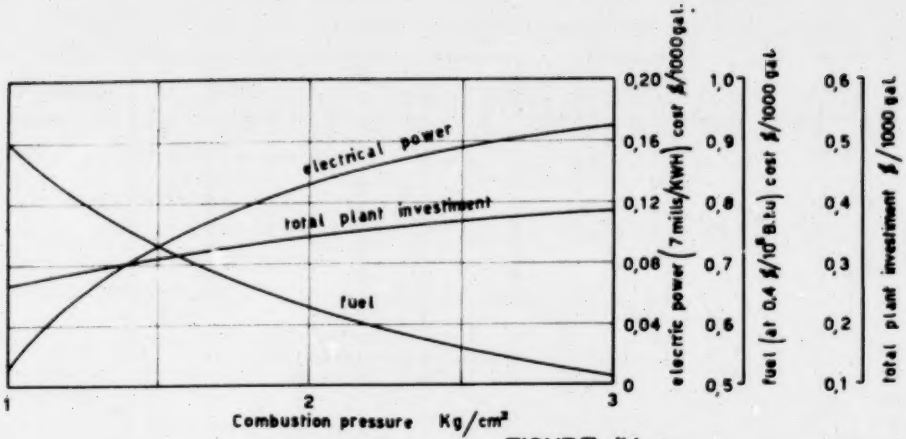

FIGURE IV

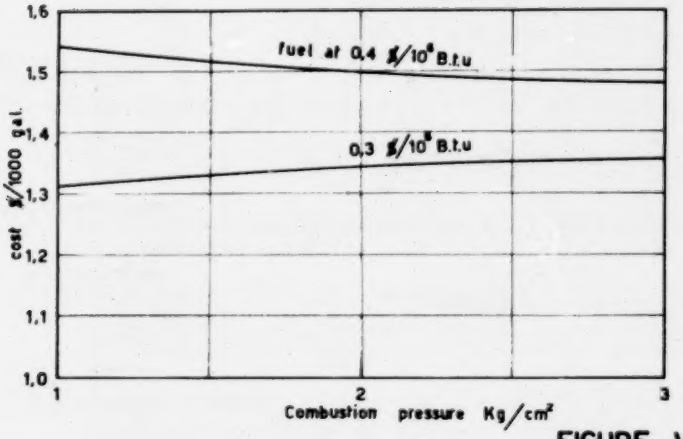

FIGURE V

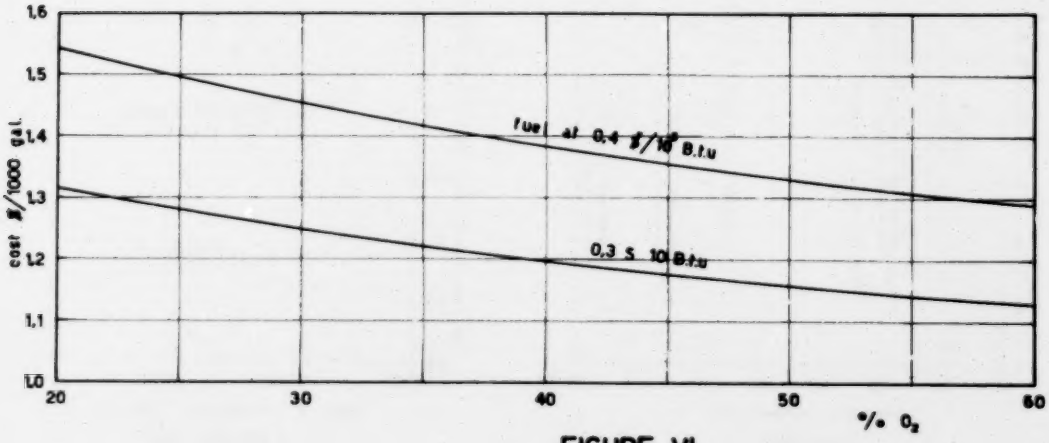

FIGURE VI

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